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U.S. DEPARTMENT OF ENERGY LABORATORY ACCREDITATION PROGRAM FOR PERSONNEL DOSIMETRY SYSTEMS (DOELAP)

R. D. Carlson, T. F. Gesell and F. L. Kalbeitzer
Radiological and Environmental Sciences Laboratory,
U.S. Department of Energy
P. L. Roberson, K. L. Jones and J. C. MacDonald
Battelle Pacific Northwest Laboratory
E. J. Vallario
Office of Nuclear Safety, U.S. Department of Energy

The U.S. Department of Energy (DOE) Office of Nuclear Safety has developed and initiated the DOE Laboratory Accreditation Program (DOELAP) for personnel dosimetry systems to assure and improve the quality of personnel dosimetry at DOE and DOE contractor facilities. It consists of a performance evaluation program that measures current performance and an applied research program that evaluates and recommends additional or improved test and performance criteria. It also provides guidance to DOE, identifying areas where technological improvements are needed.

The two performance evaluation elements in the accreditation process are performance testing and onsite assessment by technical experts. Performance testing evaluates the participant's ability to accurately and reproducibly measure dose equivalent. Tests are conducted in accident level categories for low- and high-energy photons as well as protection level categories for low- and high-energy photons, beta particles, neutrons and mixtures of these. The choice of categories depends on the unique radiation protection needs at the participant's facility. Low-energy photon sources include 4 different X-ray bremsstrahlung spectra and 2 nearly-monoenergetic K-fluorescence X-ray spectra. A Cs-137 source is used for high-energy photons. Beta sources include Tl-204, Sr-90/Y-90 and a uranium slab. The neutron sources are bare and D_2O-moderated Cf-252. The performance test for each category requires the participant to evaluate and report the dose equivalent for 15 dosimeters irradiated at the performance testing laboratory. They are irradiated in 3 groups of 5 dosimeters over a period of about 4 months. The participant generally does not know what category a particular dosimeter belongs to.

The DOELAP performance test criteria are described in the Department of Energy Standard for Performance Testing of Personnel Dosimetry Systems (DOE/EH-0027, 1986). This DOE Standard is based on the American National Standards Institute's Criteria for Testing Personnel Dosimetry Performance, ANSI N13.11-1983, but it has been written with the additional dosimetry needs of DOE facilities in mind. These include multipurpose national laboratories, high-energy accelerators and facilities that process special nuclear materials. Additional beta, X-ray, and neutron sources and additional test categories have been added to better relate test and field conditions. The DOELAP performance criteria are similar

to those specified in ANSI N13.11 but they are generally more stringent.

After a participant successfully completes performance testing in the appropriate categories, an onsite assessment of the dosimetry system is conducted. Two assessors are assigned to visit the facility. They evaluate the dosimetry program to insure that it includes a quality assurance program; up-to-date documentation describing significant procedures and practices; a program for training and retraining staff members; adequate equipment and facilities; and appropriate procedures to insure the proper use, calibration and maintenance of that equipment. This process is described in the Handbook for the Department of Energy Laboratory Accreditation Program for Personnel Dosimetry Systems (DOE/EH-0026, 1986). At the end of the onsite visit, the assessors discuss program deficiencies with appropriate members of management. Accreditation can be granted for a period of 2 years after the deficiences are corrected.

A pilot DOELAP performance test session was conducted in 1985 and a report was published in 1986 (DOE/ID-12104). Six DOE facilities voluntarily participated. The results of this pilot study were used to finalize the performance test criteria and procedures. By the fall of 1987, four additional voluntary test sessions were completed. A total of 19 dosimetry systems were tested at least once (separate neutron and beta/photon dosimeters are listed as one system), and 7 passed the performance tests in all categories they required. Principal reasons for failure included incorrect calibration methods, inadequate dose calculation algorithms, inherent limitations in the dosimeter, lack of preparation and clerical errors. The performance test results for Sessions 1-5 are summarized in Table 1.

Table 1. DOELAP Performance Test Results Through Session 5

	Category	% Passed
I.	Low-Energy Photons, High Dose	57
II.	High-Energy Photons, High Dose	82
III.	Low-Energy Photons	26
IV.	High-Energy Photons	80
V.	Beta Particles	62
VI.	Neutrons	54
VII.	Mixtures	
	III + IV	85
	III + V	22
	IV + V	74
	III + V	78
	IV + VI	85

Clearly most dosimetry systems can pass the categories involving high-energy photons. The most difficult categories have been the the low-energy photon and low-energy photon + beta mixture categories. Many dosimetry systems have difficulties in accurately measuring low-energy photons. Energy dependence problems can be very significant over this range of photon energies. These tests are designed to identify such a problem by changing the X-ray spectrum for each group of 5 dosimeters. This is a more satisfactory approach than selecting only one spectrum.

To date, about one-half of the DOE dosimetry programs have participated in the voluntary DOELAP performance tests. As a result, many are making improvements that should enable them to successfully complete the performance testing when DOELAP accreditation becomes mandatory.

The DOELAP research program identifies potential improvements in DOELAP testing categories and provides guidance for implementing these in the Standard. Some of this work is conducted in response to DOELAP participants who feel that existing sources are an inadequate test of their dosimeter for particular field conditions. Other efforts focus on evaluating calibration methods, factors for assigning delivered dose or dose equivalent, and methods used in testing dosimeter response.

The response of a personnel neutron dosimeter depends on the energy distribution of the incident neutron field. Although the DOELAP test is not designed to evaluate the participants' field calibration, it is desirable to use a test source which is roughly appropriate for the neutron energies encountered in the workplace. At present, participants choose between an unmoderated Cf-252 fission spectrum and that of a Cf-252 source moderated by a sphere of heavy water 15 cm in radius and covered by a cadmium shell 0.051 cm in thickness. The addition of an Americum-Beryllium (Am-Be) neutron source is being evaluated at the request of accelerator facilities that have higher energy neutron fields. The Cf-252 spectrum is peaked near 2 MeV with a dose equivalent average energy of 2.4 MeV. An Am-Be source has a broad spectrum maximized between 1 and 11 MeV and a dose equivalent average energy of 4.4 MeV. While an Am-Be source is not an ideal representation of neutron sprectra at high energy accelerators, it provides a better test of dosimetry systems at those facilities than does Cf-252. An Am-Be source may be added to the DOE Standard as early as 1988.

Addition of a thermal neutron category was also considered. In a feasibility study, dosimeters from five DOE participants were irradiated to thermal neutrons from a sigma pile, to thermal neutrons from a research reactor, to Cf-252 neutrons, and to selected neutron-photon mixtures. The dosimeter response for the two thermal neutron sources differed by a factor of three, because of the source geometries and differences in the neutron energy distributions. The sigma pile presented an essentially isotropic field, while the reactor configuration was a collimated beam irradiating dosimeters mounted on a phantom. After a review of the data and an informal survey of DOE facilities, it was concluded that the demand for a thermal neutron category is low because the thermal neutron dose contribution is small; most dosimeters respond adequately to thermal neutrons; the worst problem associated with thermal neutron dosimetry is a tendency for some dosimeters to falsely indicate a fast-neutron irradiation; and no masking effects were seen that would hide a significant photon or fast neutron irradiation in the presence of thermal neutrons. An additional thermal neutron category was therefore not recommended.

It has also been proposed that performance criteria should be added for dosimeter angular response. This proposal is now being evaluated. The DOELAP standard currently requires participants to measure and document the dosimeter response in two axes of rotation for angles between 0 and 85 degrees. However, the standard does not contain performance criteria for angular response. To add these, appropriate quantities must first be defined for assigning dose equivalent at nonperpendicular incidence. Then the existing recommendations for allowable dosimeter performance must be expanded to include uncertainties due to angular response. Existing models for assigning dose equivalent were reviewed. The directional dose equivalent, H', as defined in ICRU 39, was found to be an appropriate quantity for irradiations at nonperpendicular incidence, since it is additive for a multidirectional field. Performance criteria were developed based on recommendations in ICRP 35, which defines acceptable performance as accuracy within a factor of 1.5, including uncertainties from angular response. If recommended, the test of dosimeter angular response would be performed on a one-time basis, separated from the tests at perpendicular incidence.

There is considerable diversity among published conversion factors for determining dose equivalent for photon exposure or neutron fluence. Existing conversion factors for photons were reviewed in the hopes of alleviating some of the confusion caused by this diversity. Disagreement in the conversion factors is apparent, not only for the different torso models, but also for calculations using the same torso shape and tissue composition. These disagreements may be explained, in part, by the assumptions of parallel or divergent beams. The photon conversion factors used in DOELAP are based on a ten-element tissue slab model, and differ by up to 20% from the sphere calculations. These factors were verified by repeating extrapolation chamber measurements for k-fluorescence and filtered bremsstrahlung beams. Additional studies are planned for verification of conversion factors for the ICRU sphere, and a review of the impact of ICRU 39 is planned.

Other planned research includes evaluating appropriate performance criteria for CR-39 track etch dosimeters, considering the possible addition of a higher energy photon source and a low-energy beta slab source, and identifying standard methods for instrument calibrations.